Benchmarking Microprocessors for High-End Signal Processing

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There are a number of general-purpose microprocessor architectures which, while not designed for high-end signal processing, might provide the processing performance required for complex radars, signal intelligence and other demanding applications. But how well does each really perform as a digital signal processor?

To answer this question, some simple benchmarks were run on a 1GHz Freescale 7447 PowerPC, 1.8 GHz IBM 970 PowerPC, 1.8 GHz AMD Opteron and 800 MHz Broadcom MIPS-based 1250 chip.

The bottom line of this set of benchmarks is that the PowerPC with AltiVec produces impressive computational performance compared to the other processors considered. Now that IBM is shipping its PowerPC 970 with AltiVec, there is a processor alternative that addresses the memory bandwidth limitations of the 7447.

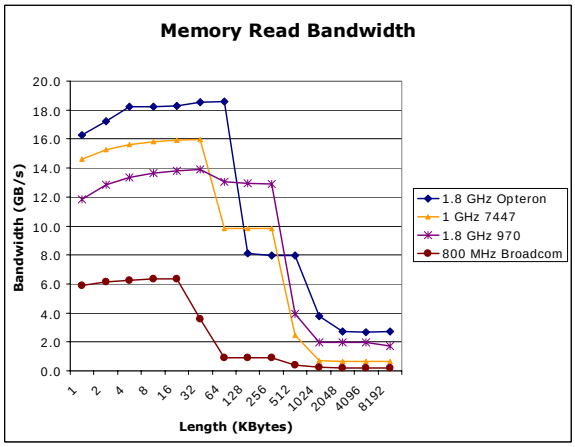
Yet, despite the strengths of AltiVec, the benchmarks revealed that the alternative processors offer some interesting capabilities for particular types of signal processing. For example, memory bandwidth may be more important than sheer speed, or where parts count is a limitation.

MEMORY READ BANDWIDTH

To measure the memory read bandwidth of the processors considered, a trivial vector-sum computation was developed. In this simple benchmark, as well as in others, all of the processors suffer a definite step down in bandwidth when vector length exceeds the L1 cache size, requiring access to L2 cache. Likewise, performance further degrades when a vector exceeds the size of the L2 cache and an access to DRAM main memory is required.

The benchmark operation consisted of summing the first byte of every 32-byte cache line and storing the result in a register, discarding most of the data from the cache line. This “for-loop” methodology was chosen because the benchmark is intended to measure bandwidth, not computational performance.

As might be expected, the 800 MHz Broadcom BCM1250, with the lowest operating frequency of the group, also has the lowest bandwidth, whether the access is to L1 or L2 cache. Despite the fact that this dual-processor chip has integrated memory controllers, it still lags behind the other processors when accessing DRAM.



The change in performance of the PowerPC 7447 is quite clear as the vector size overflows the L1 cache. The change is almost as dramatic when the L2 cache overflows, though performance for 512-Kbyte long vectors is less than expected. Where the surprises lay in this benchmark were in the behaviors of the Opteron and PowerPC 970 processors, both 1.8 GHz parts.

The Opteron chip, for example, has by far the best bandwidth of the group when operating out of L1 cache, but its DRAM bandwidth is only marginally better than the alternatives, and its L2 bandwidth lags all of the other processors except the Broadcom BCM1250.

The biggest surprise, however, lay in the behavior of the 970, which has a very fast clock. The 970 had the second slowest L1 bandwidth

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14. ABSTRACT

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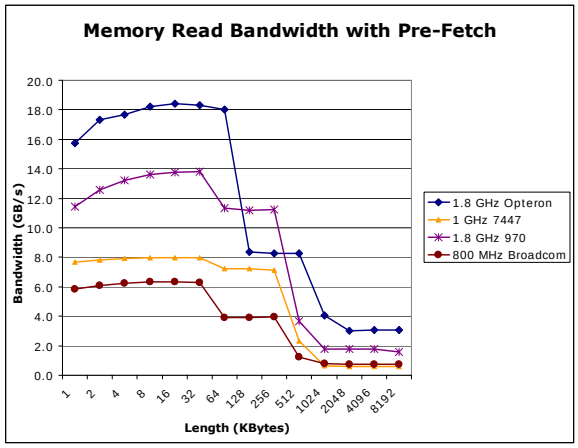
of the group - despite having almost twice the operating frequency, of the 1 GHz PowerPC 7447, for example. The reason for this appears to be the rather deep pipeline of the 970, and the trivial nature of this benchmark. More complicated tests enable the 970 to perform better when compared to other processors.

On the other hand, the benchmark results clearly showed the superior efficiency of the 970's L2 cache and automatic pre-fetch engines. The bandwidth falloff between L1 and L2 caches of this processor is quite minor, whereas the bandwidth of all the other processors in the group falls substantially when vector length forces an L2 access. The 970's pre-fetch engines analyze the memory access behavior of the application and will start fetching data from memory before the application requests it if the accesses are regular enough.

MEMORY READ BANDWIDTH WITH PRE-FETCH

All of the processor architectures considered have some programmable pre-fetch capabilities. This allows the application to predict future data requests and issue "touch" instructions to ask the processor fulfill the requests in advance. A pre-fetch factor of 3 was selected for this third benchmark, the factor being chosen somewhat arbitrarily – touches are issued 3 loop iterations ahead.



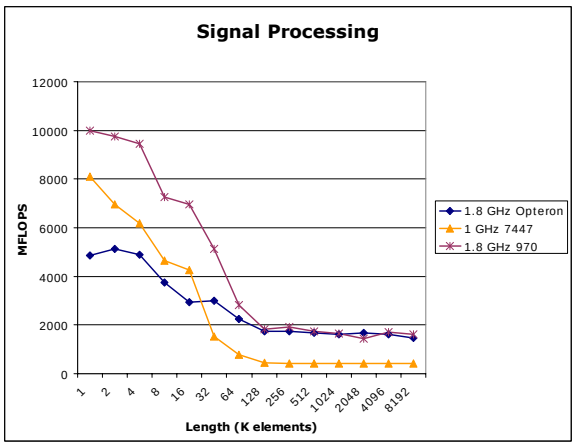
This benchmark modification had little effect on the behavior of the 970, which has built-in engines for predicting memory requests and is always doing work to optimize its memory bandwidth. Nor did the modification much affect the performance of the Opteron. The 7447s, however, suffered a serious slowdown when the vector size fits into cache.

This benchmark dramatically illustrated an important capability of the BCM1250 chip. Using pre-fetch produced dramatic improvements in L2 and DRAM bandwidth. DRAM bandwidth, for example, went up by a factor of 6. Performance approaching the 7447 bandwidth is possible with additional pre-fetch.

As for the 7447, although there are some dependencies on the system controller chip used, the general lesson is that the programmer needs to be careful with pre-fetch. The advisability of pre-fetching will depend on the algorithm.

Digital Signal Processing

The final benchmark reported here reveals how three of the processors perform when running a simplistic signal processing application. For this test, the assumed source is a sensor such as a radar receiver, providing 16-bit integer data, which has then been digitized.



In the benchmark, the data is converted to float, then a forward FFT is performed, followed by a vector multiply and an inverse FFT. This resembles "pulse compression" in radar where a convolution is performed on the input data, or a frequency domain filter used in signal intelligence. The shape of these curves and the relative performance of the processors is dominated by the FFT performance. AltiVec provides a clear advantage here.

Project Goal

Abstract
Agenda

Evaluate various general-purpose processors in Radar Signal Processing

- Requires processing of complex data types
- All processors have SIMD capability

Freescale 744x (G4) is popular, but several potential alternatives have become available recently

NOT evaluated for this project: DSP chips, FPGA solutions

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Configurations

	AMD Opteron	Broadcom BCM1250	IBM PowerPC 970	Motorola/ Freescale PowerPC 7447 (G4)
Frequency	1.8 GHz	800 MHz	1.8 GHz	1.0 GHz
On-chip cache (L1)	64 Kbytes	32 Kbytes	32 Kbytes	32 Kbytes
On-chip cache (L2)	1024 Kbytes	512 Kbytes (shared by processors)	512 Kbytes	512 Kbytes
L3 Cache	None	None	None	None
Memory Controller	Dual-channel on-chip	Dual-channel on-chip	Apple dual channel, external	Discovery II single channel
DRAM	128 bits, 133 MHz DDR (PC2100)	128 bits, 133 MHz DDR (PC2100)	128 bits, 200 MHz DDR (PC3200)	64 bits, 133 MHz DDR (PC2100)
Comments		Dual processors on chip	Apple dual-processor SMP configuration	

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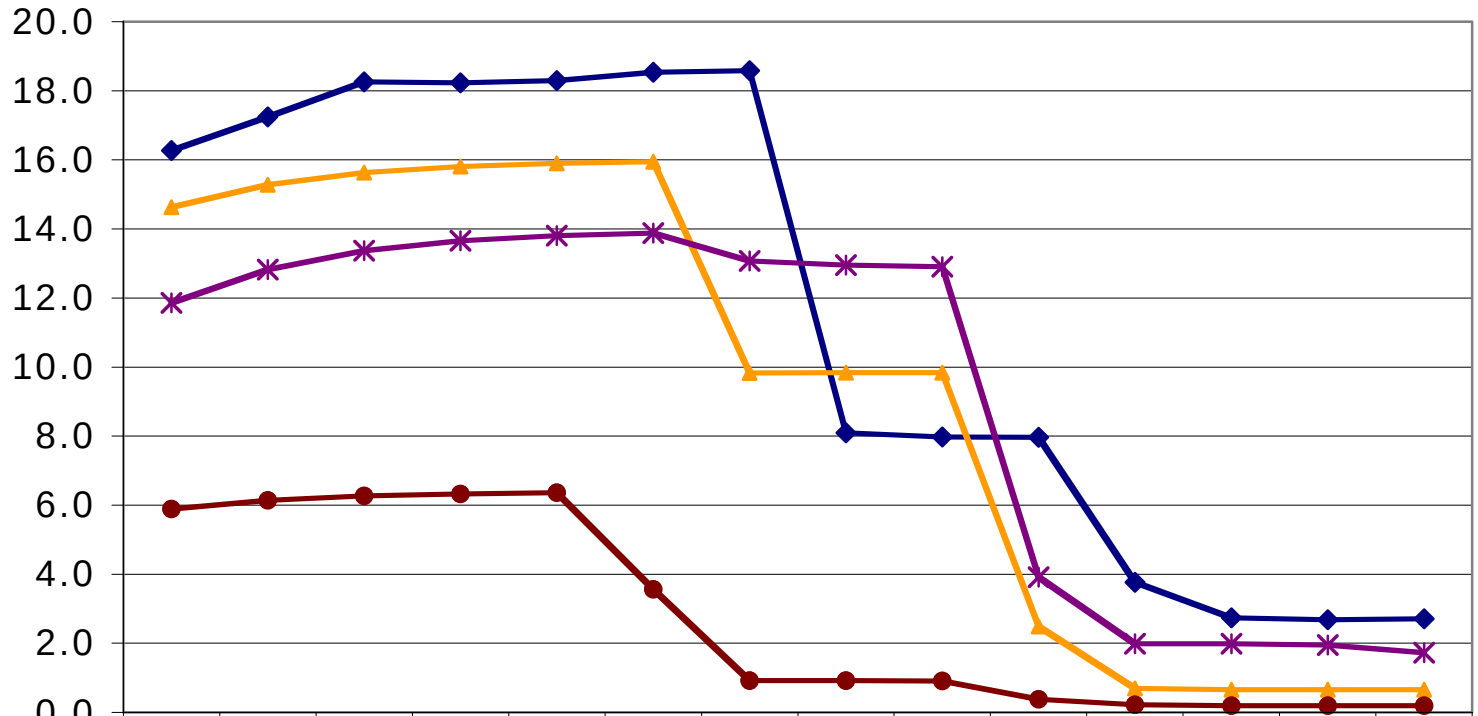
Memory Read Bandwidth



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	16.3	17.2	18.3	18.2	18.3	18.5	18.6	8.09	7.98	7.97	3.77	2.74	2.68	2.71
1 GHz 7447	14.6	15.3	15.6	15.8	15.9	15.9	9.83	9.84	9.83	2.49	0.70	0.66	0.66	0.66
1.8 GHz 970	11.9	12.8	13.4	13.7	13.8	13.9	13.1	13.0	12.9	3.91	1.99	1.99	1.95	1.72
800 MHz Broadcom	5.89	6.13	6.26	6.33	6.36	3.56	0.91	0.91	0.91	0.38	0.23	0.20	0.20	0.20

Length (KBytes)

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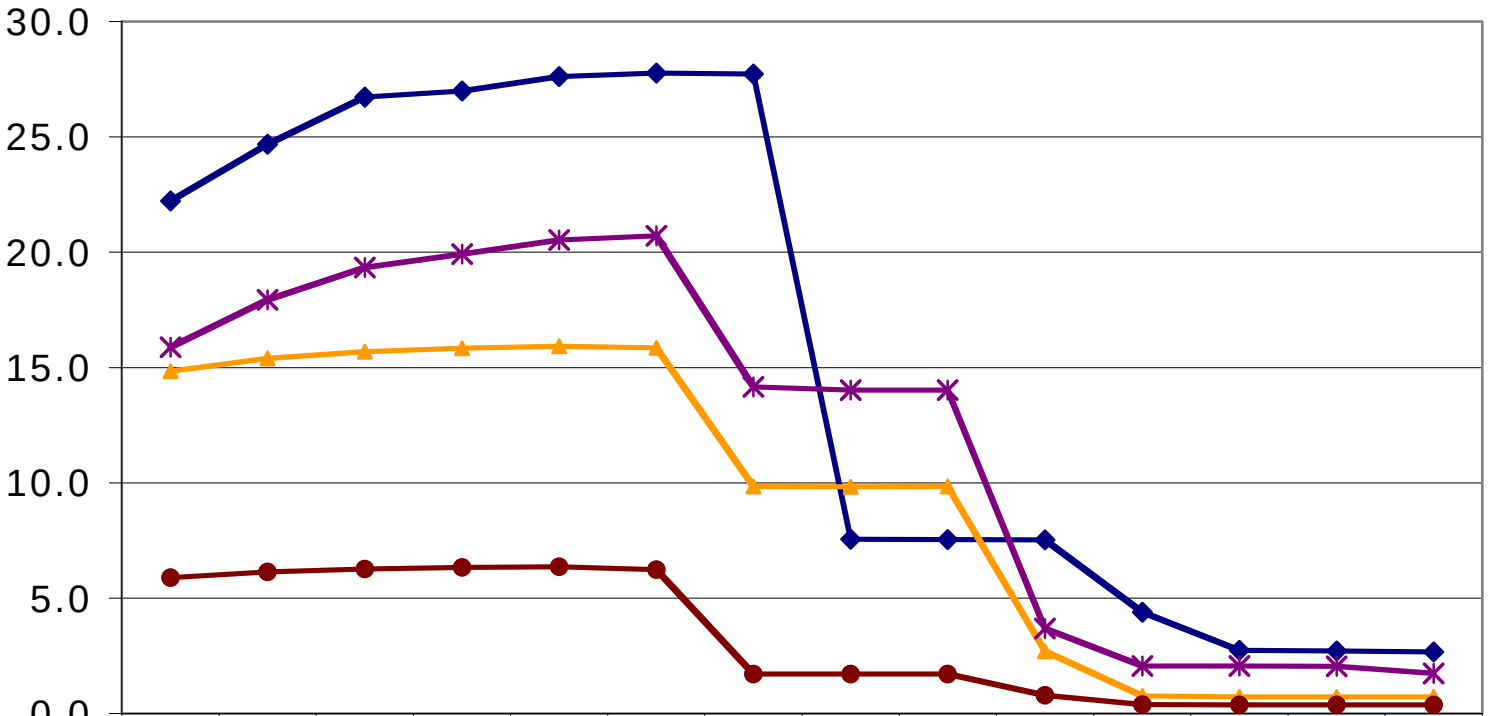
Read Bandwidth - Unrolled



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	22.2	24.7	26.7	27.0	27.6	27.8	27.7	7.55	7.55	7.53	4.38	2.74	2.70	2.67
1 GHz 7447	14.8	15.4	15.7	15.8	15.9	15.9	9.84	9.83	9.84	2.70	0.76	0.73	0.73	0.73
1.8 GHz 970	15.9	17.9	19.3	19.9	20.5	20.7	14.2	14.0	14.0	3.68	2.06	2.06	2.04	1.74
800 MHz Broadcom	5.89	6.14	6.27	6.33	6.37	6.24	1.71	1.71	1.71	0.79	0.39	0.38	0.38	0.37

Length (KBytes)

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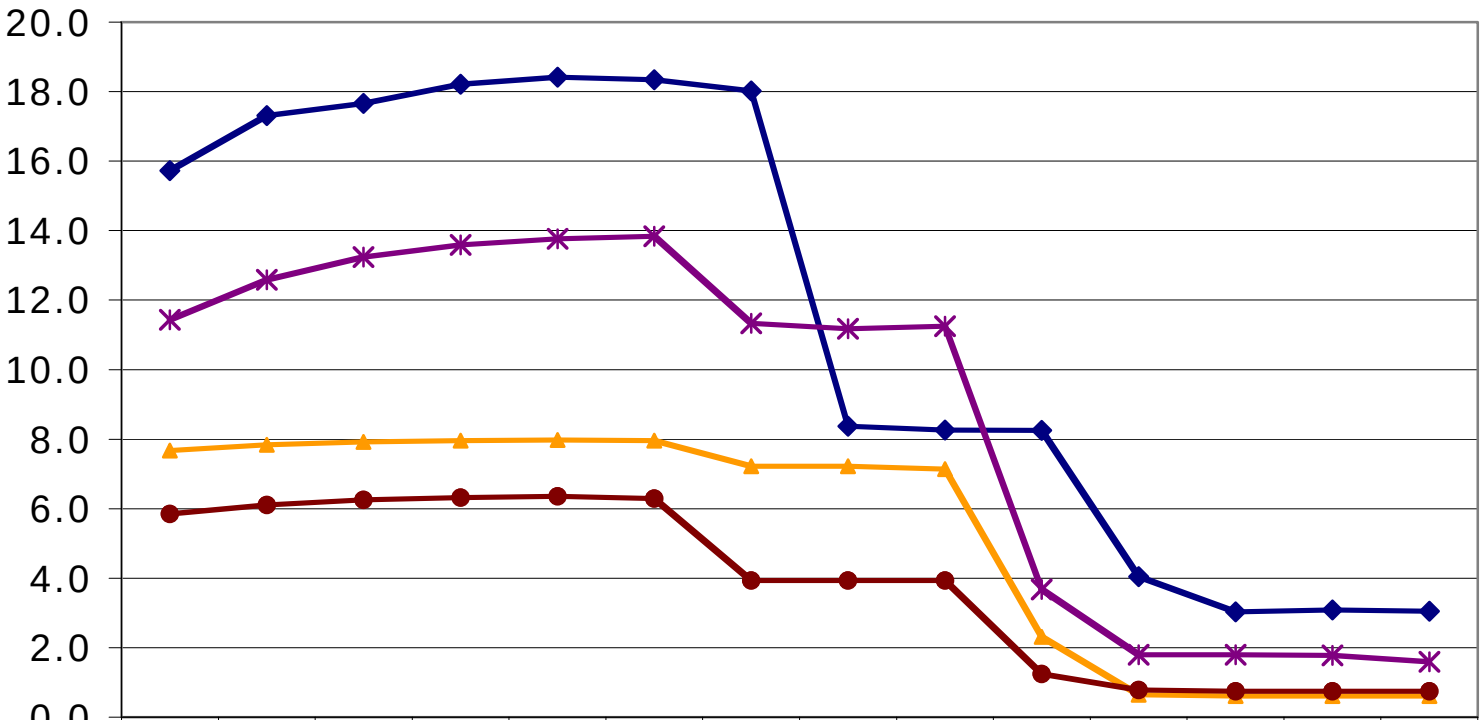
Read Bandwidth with Pre-Fetch



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	15.7	17.3	17.7	18.2	18.4	18.3	18.0	8.37	8.27	8.25	4.04	3.03	3.09	3.05
1 GHz 7447	7.7	7.8	7.9	8.0	8.0	8.0	7.22	7.22	7.14	2.31	0.65	0.61	0.60	0.60
1.8 GHz 970	11.4	12.6	13.2	13.6	13.8	13.8	11.3	11.2	11.3	3.68	1.79	1.80	1.78	1.60
800 MHz Broadcom	5.85	6.11	6.25	6.32	6.35	6.29	3.93	3.94	3.94	1.24	0.79	0.75	0.75	0.74

Length (KBytes)

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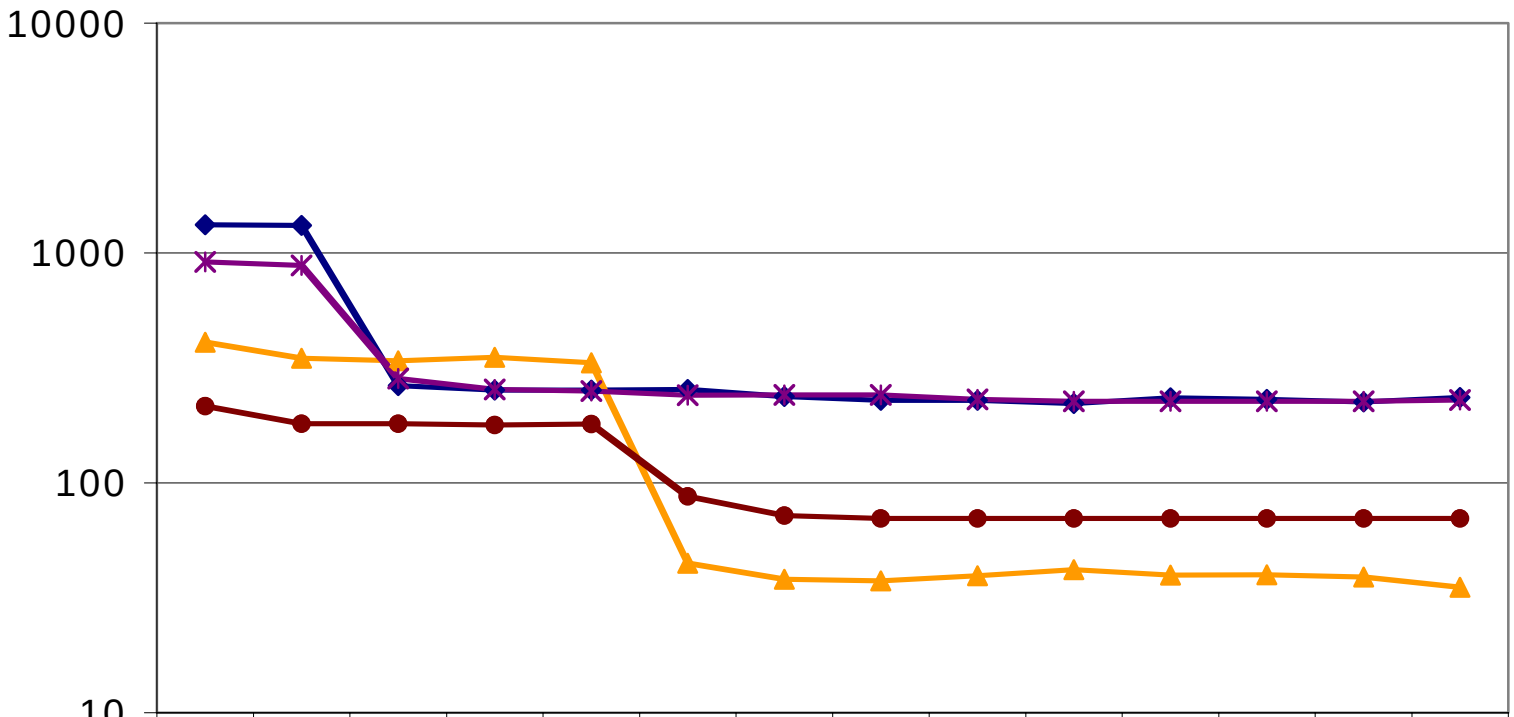
Complex Vector Multiply - Scalar C



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	1325	1319	265	254	253	255	238	229	229	222	235	231	225	236
1 GHz 7447	409	349	340	351	333	45	38	37	39	42	40	40	39	35
1.8 GHz 970	915	881	284	255	251	241	241	242	231	227	227	226	227	230
800 MHz Broadcom	216	181	181	179	180	88	72	70	70	70	70	70	70	70

Length (K elements)

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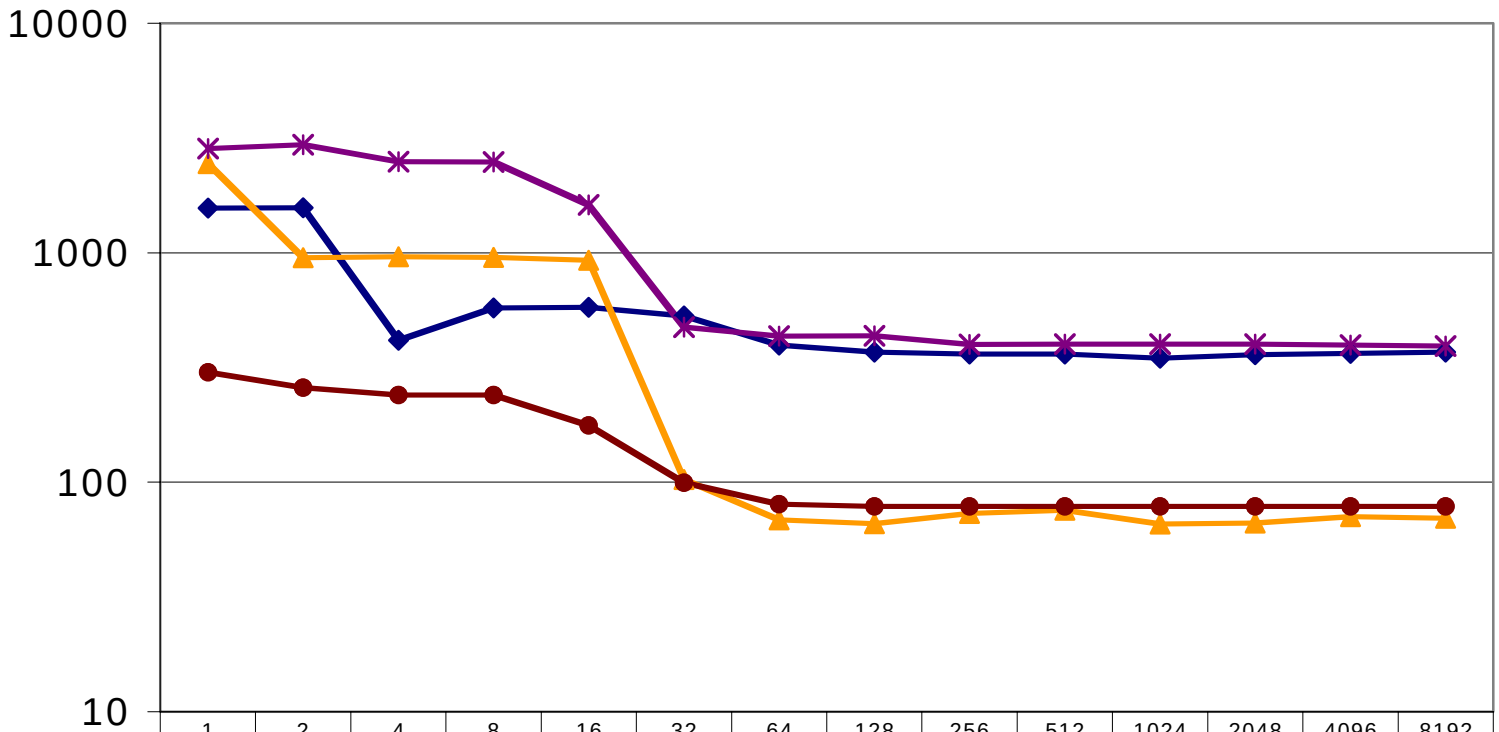
Complex Vector Multiply using SIMD



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	1566	1570	415	575	578	530	396	369	362	362	347	359	365	369
1 GHz 7447	2446	953	961	954	928	103	69	66	73	76	66	66	71	70
1.8 GHz 970	2849	2957	2492	2490	1619	474	433	435	398	400	400	400	396	392
800 MHz Broadcom	301	258	240	240	177	100	80	78	78	78	78	78	78	78

Length (K elements)

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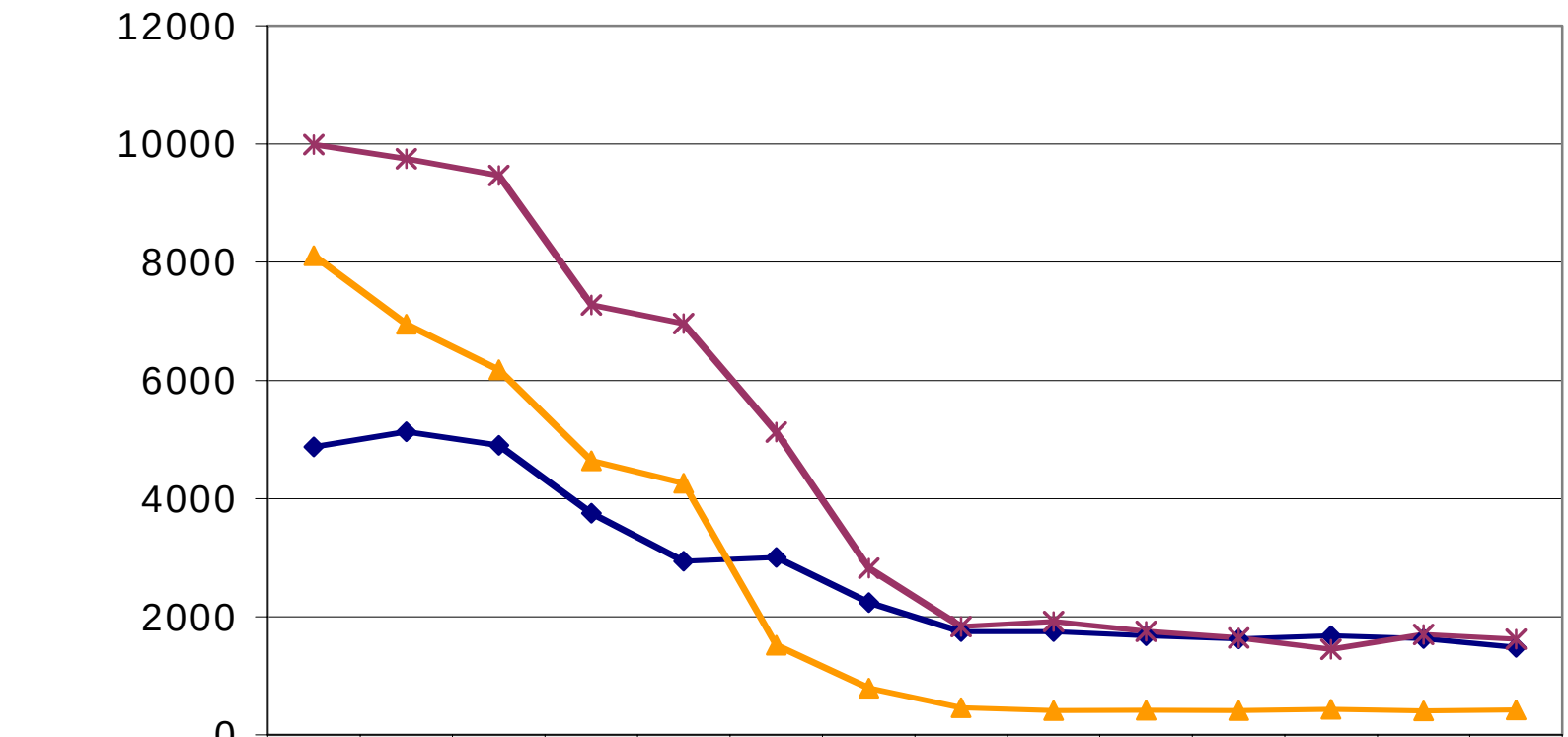
Signal Processing



	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192
1.8 GHz Opteron	4874	5130	4904	3754	2939	3007	2240	1747	1746	1680	1625	1678	1629	1483
1 GHz 7447	8110	6951	6178	4642	4260	1520	792	461	413	419	409	434	407	424
1.8 GHz 970	9992	9750	9464	7273	6958	5127	2824	1836	1919	1753	1641	1447	1701	1619

Length (K elements)

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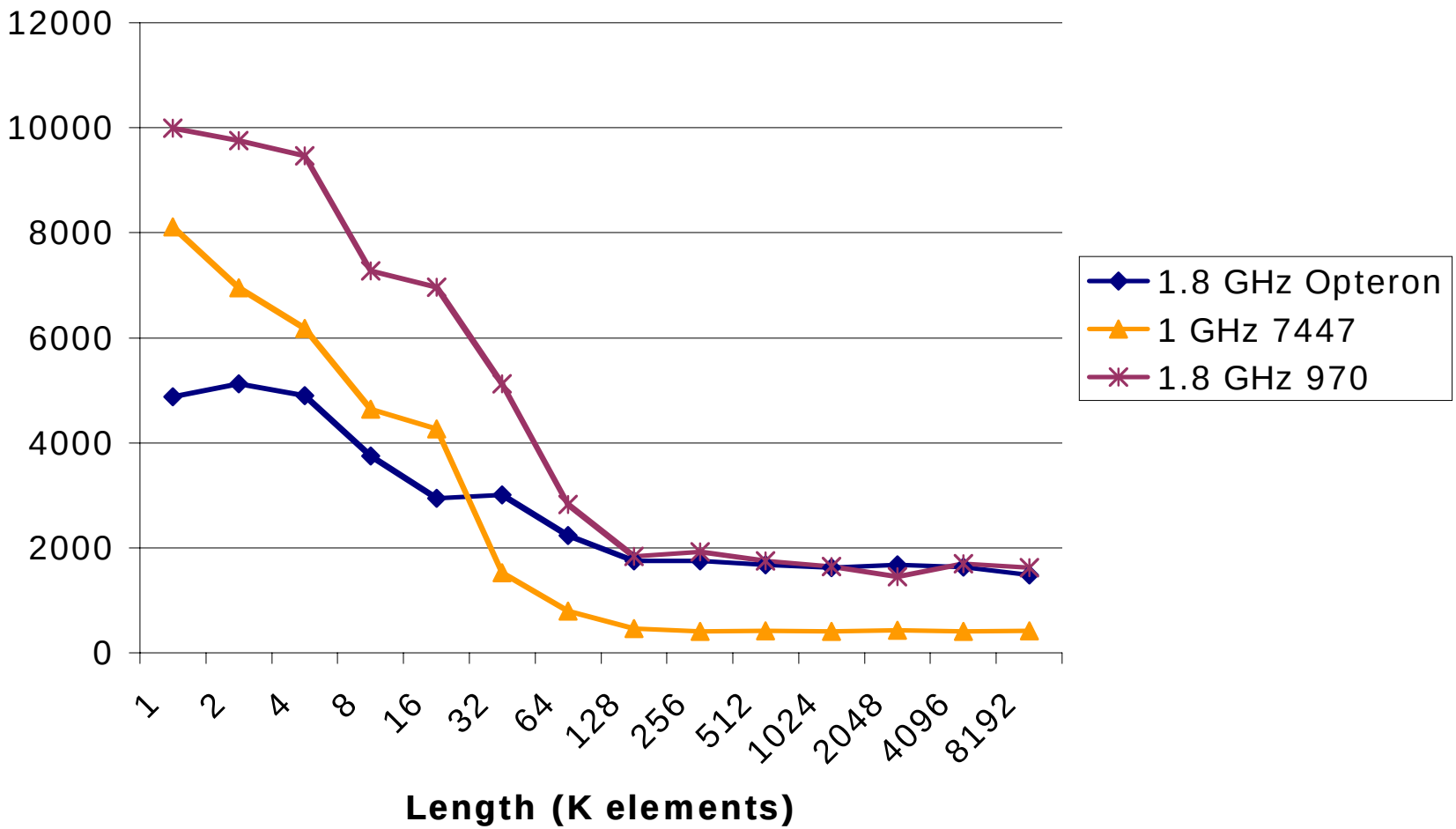
Signal Processing